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# PHYSIOLOGICAL RESPONSES TO HIGH INTENSITY

## INTERMITTENT SOUND·

BY

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ABSTRACT

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INTERMITTENT SOUND

Eighteen subjects were exposed to brief periods of high intensity intermittent sound at 3 pulses per second and at levels of from 100 to 120 db. Skin temperature, skin impedance, EKG and continuous systolic blood pressure from the finger were recorded. The results indicated little or no effect on all the measures except GSR which showed a linear increase in magnitude of response with an increase in intensity of sound. Comparisons with previous reports and some tentative explanations are presented.

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Physiological Responses to High Intensity

Intermittent Sound [1]

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A number of studies have shown that intermittent stimulation at low frequencies (particularly in the range from one to twenty pulses per second) produces unexpected effects on behavior (Plutchik, 1959). For example, a series of pulses is judged to be louder than a steady tone of the same intensity level (Garner, 1948), blood oxygen-saturation levels are depressed by intermittent stimulation (Lovett-Doust, Hoenig and Schneider, 1952), and EEG rhythms are modified (Goldman, 1952; Neher, 1961).

There are several reasons why the effects of such sounds on physiological responses need to be evaluated. First, although many experiments use tones of various sorts as signals or as cues, most do not specify the actual magnitude of tone, and there is thus no way of directly comparing different studies. Secondly, there is also the problem of the likelihood of unconditioned responses to the signal itself.

Some recent reports indicate that intensity of the conditioned stimulus affects conditioning in complex ways (Grings, 1960). For example, Kimmel (1959) found that pseudoconditioning or "sensitization" of GSR occurred using CS tones of 75 or 115 decibels, while true conditioning occurred only with a CS at 35 db. Pseudoconditioning of the GSR was also reported by Stewart, Stern, Winokur and Fredman (1961) using a CS at 65 decibels. Similarly, pseudoconditioning was found in rats trained on an avoidance task when the CS was a 65 or 85 db buzzer but not, curiously enough, when it was a 60 or 80 db pure tone (Myers, 1962). These observations suggest the need for a knowledge of how magnitude of stimulation affects the various response measures used. Thus far, GSR, muscle tension and certain cardiovascular measures have been studied in relation to stimulus

intensity (Davis, Buchwald, and Frankmann, 1955; Hovland and Riesen 1940), but a number of unexplored variables remains.

## Method

Sixteen college students, eleven females and five males, ranging in age from 17 to 20 served as subjects. All of the subjects showed normal hearing in the 1,000 to 8,000 cps range when initially tested by a Maico audiometer.

Before the physiological recording apparatus was attached to the subjects, their pain threshold for sound was ascertained by the method of limits using an ascending order of presentation. The sound level in decibels at pain threshold was then considered to be the "high intensity" stimulus. Ten decibels below the pain threshold was considered the "medium intensity" stimulus, and ten decibels below the medium intensity was the "low intensity" sound stimulus. The mean for the high intensity stimulus was approximately 120 decibels, for the medium intensity 110 db., and for the low intensity, 100 db.

The stimulus was a 2,500 cps sound pulsed at 3 beats per second, and set at a previously determined intensity for each subject. It was presented through a set of PDR-8 binaural headphones with doughnut cushions, which had been calibrated into a 6-cc coupler. These tones were produced by a Hewlett-Packard audio oscillator and were routed through a modulator circuit for shaping the pulses, a power amplifier and an attenuator. The apparatus is described more fully in Plutchik (1961).

At the start of the testing session, after the subject's pain thresholds had been determined, the subjects were asked to recline on a cot. At this time, systolic and diastolic pressures were recorded, utilizing a Tycos sphygmomanometer and stethoscope. Remaining in this semi-reclining position, the subjects then had the apparatus attached to them. This included instruments to record systolic blood pressure, heart rate, skin impedance, and skin temperature.

Continuous systolic blood pressure measurement was monitored through a continuous systolic monitor, made by Biophysical Electronics. A crystalline quartz pick-up and pressure cuff was placed on the middle finger of the subject's right hand. The sensitivity of the quartz pick-up was adjusted so that the systolic pressure at the beginning of the recording sessions was roughly equivalent to the systolic pressure as measured by the sphygmomanometer and stethoscope method at the beginning of the session.

Two stainless steel electrodes made by Stoelting, with a surface area of one inch by 3/4 of an inch, were attached with adhesive tape to the ventral surfaces of the subject's second and fourth fingers of the left hand. Into these was fed a pulsating direct current which changed polarity 60 times a second, each pulse being a square wave. The DC pulses were produced by a model 230 Applegate constant current generator. The skin impedance changes were measured by the voltage needed to keep the current at the electrodes constant at 80 microamperes. This was measured by an RCA Senior Voltohmist, a vacuum tube voltmeter with a 3% accuracy full scale.

Prior to testing the subjects, a calibration measure was determined for the amount of spontaneous variation due to electrode polarization. The electrodes were suspended in a 3% saline solution, and a constant current of 80 microamperes was introduced into them via the Applegate constant current generator across a 50K ohm fixed resistor. Over an eight hour period of time, taking readings from the RCA Senior Voltohmist Voltmeter, no discernable variations were found.

On the ventral surface of the middle finger of the left hand, a thermister was taped to allow for continuous recording of skin temperature by a Yellow Springs Tele-thermometer.

Heart rate measurements were recorded from the right and left forearms, with the right leg connected to the ground. The electrodes were attached in the conventional manner, utilizing electrode jelly, and held in place with cloth straps. The electrical impulses were amplified and recorded by a standard EKG, the BeckLeed Cardi-All.

The measurements were made visually from dials for systolic blood pressure, skin impedance, and skin temperature. These records were taken during the last five seconds of each of the 15 second intervals into which the recording trials had been divided. Heart rate measurements were translated from the wax paper records of the BeckLeed Cardi-All in 15 second intervals.

The subjects, who had been asked to follow their normal routine prior to the testing situation, were asked to relax during the hour testing period. They were asked to try to keep all body movement at a minimum during each of the nine recording trials.

After the subjects were attached to the apparatus, a five minute recording of resting levels was taken to provide an index of their basal physiological states.

After the initial resting level recording, nine more recordings were taken. Each recording lasted for two minutes and fifteen seconds. In the first 15 seconds of the second minute of recording time, the auditory stimulus was presented. The three intensities of sound were presented three times each in counterbalanced order during the sequence of testing.

Between the end of one recording session, and the beginning of the next session, there was, randomly, a rest interval of from two to four minutes.

The sixteen subjects were divided into two groups. One group was presented the auditory stimulus monaurally, and the other received binaural stimulation.

The mean values of the physiological measures for 15 seconds prior to stimulation, for the 15 seconds of stimulus presentation, and for the 15 seconds post stimulation were computed for all subjects.

## Results

A comparison of the mean values for the pain thresholds of the monaural and the binaural stimulation groups indicated no difference in pain thresholds between the two groups. The eight subjects having monaural stimulation had a mean value of 120 decibels, while the eight receiving binaural stimulation had a mean value of 119 decibels. Hence, all the resulting data was compiled into one group.

Table 1 shows the mean blood pressure values for the three intensities used and for the 15 second prestimulus, stimulus and post-stimulus periods. The intro- duction of the sound did not produce any consistent direction change, or changes of any significant magnitude. Each of the means is based on approximately 48 recordings. In a few cases, where a subject showed a sudden transient increase over 170 mm. Hg., it was assumed to reflect a movement artifact, and was not counted.

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Insert Table 1 about here
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Table 1 shows the GSR changes associated with high intensity sound stimulation. It indicates clearly a linear decrease in voltage with an increase in the loudness of the sound. This data is shown plotted in figure 1 as impedance changes as a function of intensity of stimulation.

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Insert Figure 1 about here
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In table 1 is also shown the skin temperature data for the 16 subjects, with three readings per subject. The amount of change as a result of introducing the sounds is either zero or a fraction of one degree and not related to intensity. An examination of the original data indicates that 12 of the 16 subjects did not change at all in skin temperature when the sound was introduced. Thus the data reported are actually based on the four subjects whose skin temperature changed even slightly. This suggests that skin temperature under the conditions of this

experiment was not affected by high intensity sound. It might parenthetically be added that a frequency distribution of initial finger temperature levels shows that most of the subjects had temperatures between 20 and 26° centigrade, which is actually at the lower end of the skin temperature distribution. When a subject's temperature changed, it was usually in the direction of an increase, thus suggesting the possible operation of an initial level variable, although the data is insufficient to be conclusive on this point.

Table 1 also presents the EKG changes to high intensity sound. The mean amount of change appears unrelated to intensity and varies less than 1 beat per minute to less than 3 beats, and is inconsistent in direction. This implies that heart rate is unaffected by the sound levels used in this experiment.

## Discussion

Under the conditions of the experiment reported here only the GSR showed any definite change with intensity of sound. A linear increase in the size of the GSR as a function of intensity has been reported by Hovland and Riesen (1940) and by Davis, Buchwald and Frankmann (1955) in exactly the same range. This correspondence is interesting in light of the fact that Hovland and Riesen measured skin potential and not skin impedance as was done here. What is perhaps more puzzling is that little or no effects on systolic blood pressure, heart rate and skin temperature were observed.

It has, of course, been noted generally, that GSR changes are more consistently related to stimulation than other measures. Richter (1928) has written "skin resistance is subject to much wider fluctuations than almost any of the other physiological functions of the body. Those most commonly known, body temperature, pulse rate, respiration, basal metabolic rate, etc., all remain extraordinarily constant from day to day and from person to person, except under pathological conditions." Alexander and Horner (1961) similarly state "we are limiting ourselves to the statistical evaluation of the psychogalvanic reflex responses

since this parameter of our polygraphic data has been found to be the most readily established and the most consistent in its quantitative aspects."

The recent study by Kaelbling, King, Achenbach, Branson and Pasamanick (1960) dealing with rhe reliability of autonomic responses, similarly found that neither an intense auditory startle stimulus nor electric shock were able to produce significant increases in heart rate although GSR changed reliably for all stimuli. Although the Davis et al (1955) experiment did report heart rate changes to a single 98 decibel tone, when the stimulus was repeated at regular one minute intervals, no significant adaptation effect was found.

There are at least two possible ways to account for the apparent lack of effect on the three physiological measures used. Since the repetitive sound stimulus was on for 15 seconds, it is possible that any initial transient heart rate or blood pressure response was obscured by the subsequent reactions. Kaelbling et al (1960) considered this same possibility and tried getting heart rate for the seven beats before and the seven beats after the stimulus instead of using a 10 second prestimulus period and a 20 second poststimulus period. The results showed no change in the reliability of this measure. Despite this it seems reasonable to consider the duration of stimulation as a meaningful parameter to explore systematically. This is particularly important in the light of Davis's et al (1955) observation that the heart rate response to a single tone is diphasic, i.e., it increases and then decreases. It is possible that a train of pulses tends to average out this effect, although certain pulse rates might facilitate either the rise or fall aspects of heart rate change. Thus, stimulation rate might also be explored systematically.

A second point to consider is that there was no definite evidence of adaptation effects, the responses at the end of the experimental session were not systematically different from the earlier ones. This may mean that asymptotic adaptation levels were rapidly established and remained fairly constant throughout the experiment. On the other hand, the results may relate to Grings' concept of

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the "perceptual disparity response." He has shown that the magnitude of the GSR
depends in part upon the difference between the magnitude of the stimulus he is
expecting and what he receives.  Since the three intensity conditions were pre-
sented in counterbalanced orders so that the subject was never certain of what
to expect, there was little opportunity for any adaptation to take place.  The
subject was, in essence, presented with new stimuli on each trial.

In general, the results seem to justify the conclusion that the physiological
measures used under these conditions (with the exception of the GSR) are not
reactive to high intensity intermittent sound.

## Summary and Conclusions

Eighteen subjects were exposed to brief periods of high intensity intermittent
sound at 3 pulses per second and at levels of from 100 to 120 db.  Skin temperature,
skin impedance, EKG and continuous systolic blood pressure from the finger were
recorded.  The results indicated little or no effect on all the measures except GSR
which showed a linear increase in magnitude of response with an increase in
intensity of sound.  Comparisons with previous reports and some tentative
explanations are presented.

## Table 1

### Physiological Changes to High Intensity

### Intermittent Sound

| Mean SPL (db) | Mean Pre-Stimulus Level | Mean Stimulus Level | Mean Amount of Change | Mean Post Stimulus Level |
|---|---|---|---|---|
| | | Blood Pressure | | |
| 100 | 123.57 | 123.30 | -0.27 | 124.66 |
| 110 | 124.80 | 126.62 | +1.82 | 125.14 |
| 120 | 127.58 | 127.73 | +0.15 | 124.76 |
| | | GSR | | |
| 100 | 11.43 | 11.17 | -0.26 | 11.29 |
| 110 | 11.07 | 10.65 | -0.42 | 10.79 |
| 120 | 11.13 | 10.56 | -0.57 | 10.65 |
| | | Skin Temperature | | |
| 100 | 24.07 | 24.85 | +0.78 | 24.49 |
| 110 | 24.49 | 24.49 | +0.00 | 24.49 |
| 120 | 24.27 | 24.34 | +0.07 | 24.34 |
| | | EKG * | | |
| 100 | 18.66 | 18.70 | +0.04 | 18.34 |
| 110 | 18.69 | 18.00 | -0.69 | 18.87 |
| 120 | 18.50 | 18.52 | +0.02 | 18.78 |

* The figures in this table represent the mean number of beats in a 15 second interval.
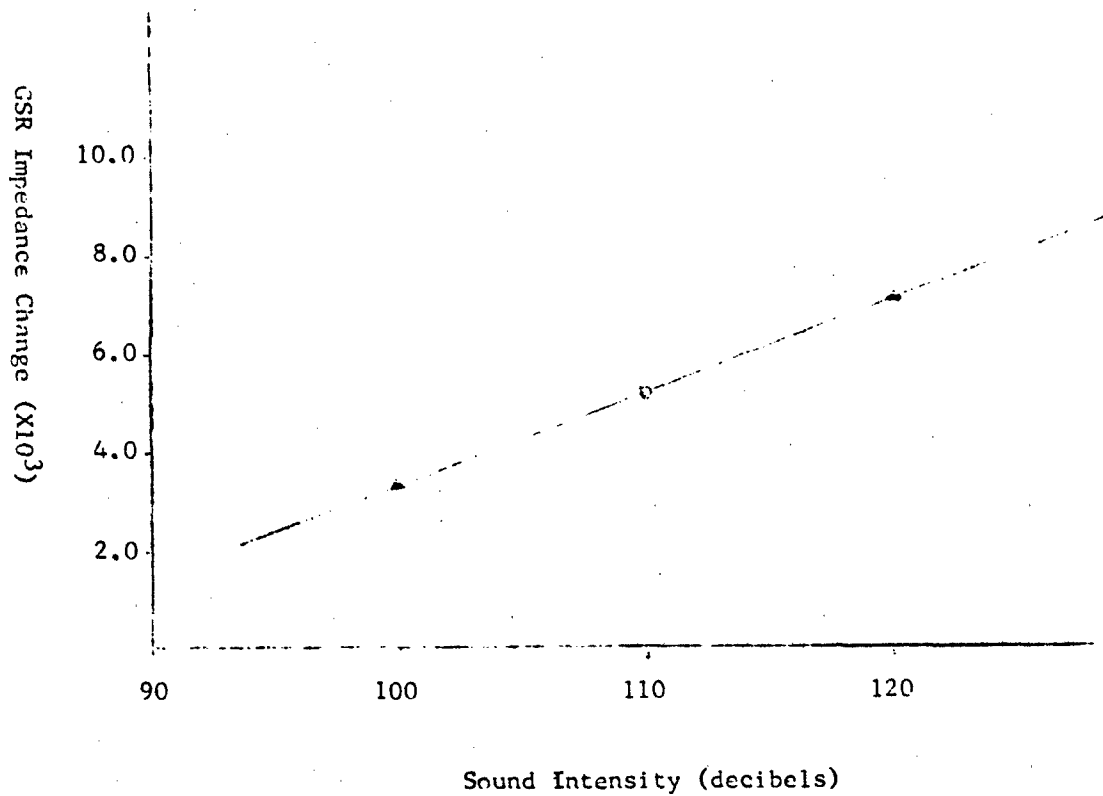
Fig. 1.  GSR impedance change as a function of sound intensity at

3 pulses per second.  Each point is a mean based upon 48 values.

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psychogalvanic reflex in man.  J. Neuropsychiat., 1961, 2, 246-261.

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Footnotes

2.  Currently on leave from Hofstra College, Hempstead, New York.